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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EEL1206 – INTRODUCTION TO MACHINES AND POWER SYSTEMS

(EE, CE, MCE, ME, TE, OPE, NT)

6 MARCH 2019
9.00 a.m - 11.00 a.m
(2 Hours)

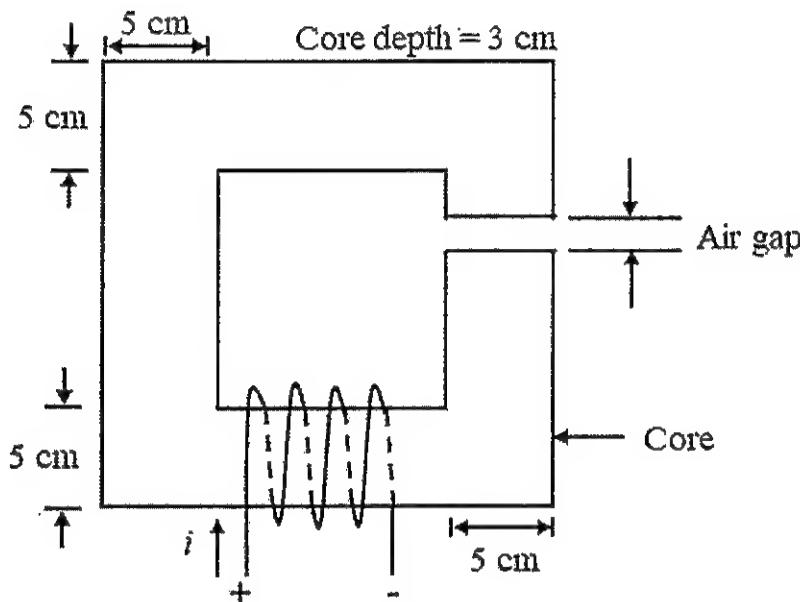
INSTRUCTIONS TO STUDENTS

1. This question paper consists of 8 pages including the cover page and Appendix. There are **FOUR** questions in this paper.
2. Attempt **ALL** questions. All questions carry equal marks and the distribution of marks for each question is given.
3. Some useful formulae are given in the Appendix section.
4. Please write all your answers in the Answer Booklet provided.

Question 1

(a) A ferromagnetic core with an effective mean path length of 85 cm has a 300-turn coil wrapped around one leg as shown in Figure Q1(a). The core has a relative permeability of 1200 and the air gap of the core is 0.2 mm. Due to the fringing effects, the effective area of the air gap is 15% larger than the physical core area. A flux density of 0.8 T is to be established in the air gap.

- Calculate the total reluctance of the ferromagnetic core structure. [5 marks]
- Find the magnetic field intensity of the air gap. [2 marks]
- Determine the current, i . [3 marks]

**Figure Q1(a)**

(b) A balanced wye-connected load having an impedance of $(15+j18)\Omega$ per phase is connected to a three-phase line as shown in Figure Q1(b). The line impedance is $(5+j2)\Omega$ per phase. The line is supplied by a three-phase source with line-to-line voltage of 480 V. Given $V_{bc} = 480\angle -30^\circ$ V and assuming a positive sequence for the source voltages:

- Find the phase voltages V_{an} , V_{bn} , and V_{cn} . [4 marks]
- Determine the line currents I_a , I_b , and I_c . [5 marks]

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(iii) Compute the apparent and complex power at the load side. [4 marks]

(iv) Calculate the source's power factor. [2 marks]

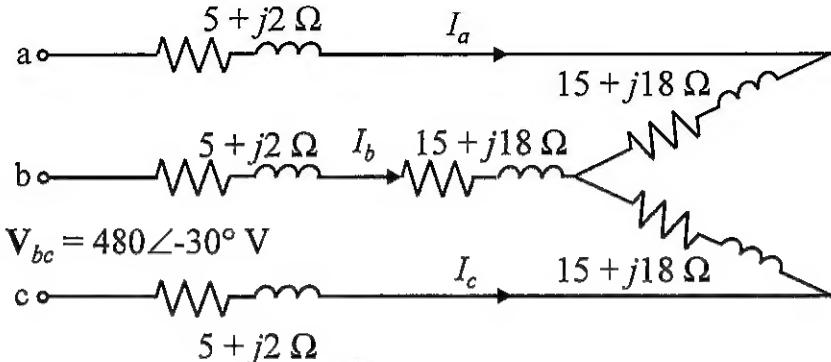


Figure Q1(b)

Question 2

(a) List and describe the THREE special-purpose transformers. [6 marks]

(b) A 200-kVA, 11000/415-V, 50-Hz single-phase power transformer has impedances as shown in Table Q2. The core loss resistance and magnetizing reactance referred to the primary side are $55 \text{ k}\Omega$ and $33 \text{ k}\Omega$, respectively.

Primary winding	Secondary winding
$R_p = 6 \Omega$	$R_s = 0.02 \Omega$
$X_p = 12 \Omega$	$X_s = 0.03 \Omega$

Table Q2

(i) Determine the values for the parameters in the approximate equivalent circuit of this transformer referred to the secondary side. [7 marks]

(ii) Draw the schematic diagram of the transformer's approximate equivalent circuit and label all voltages, currents and impedances. [3 marks]

(iii) Calculate the full-load voltage regulation at 0.83 power factor (PF) lagging. [5 marks]

(iv) Find the efficiency of the transformer at full load with 0.83 PF lagging. [4 marks]

Continued...

Question 3

(a) Briefly describe the following **FOUR** types of losses in machines:

- Copper losses
- Mechanical losses
- Core losses
- Rotational losses

[4 marks]

(b) A 30-hp, 240-V DC shunt motor with compensating windings has an armature resistance R_A of 0.2Ω . Its field circuit has a total resistance $R_{adj} + R_F$ of 240Ω , which produces a no-load speed of 1800 rpm.

(i) Draw the equivalent circuit of the motor. [2 marks]

(ii) Find the motor speed n_m and the induced torque τ_{ind} when the input current is 110 A. [6 marks]

(c) The DC test, no-load test, and locked rotor test can be used to determine the parameters for induction motor equivalent circuit. Associate the equivalent circuit parameters to each of these tests. [3 marks]

(d) A 50-kW, 460-V, 50-Hz, two-pole induction motor has a slip of 5% when operating a full-load conditions. At full-load conditions, the friction and windage losses are 700 W, and the core losses are 600 W. Find the following values for full-load conditions:

(i) The speed of the magnetic field n_s . [2 marks]

(ii) The speed of the shaft n_m . [2 marks]

(iii) The output power P_{out} and the converted power P_{conv} in watts. [2 marks]

(iv) The load torque τ_{load} in newton-meters. [2 marks]

(v) The induced torque τ_{ind} in newton-meters. [2 marks]

Continued...

Question 4

(a) Figure Q4(a) shows the simulated daily load curve on a typical power system, which depicts the variations in the power demand at different time of the day. Different modes of power plant operation are required to support the fluctuations in the power demand. Briefly explain the following:

- Base load mode
- Intermediate load mode
- Peak load mode
- Non-dispatchable mode

[4 marks]

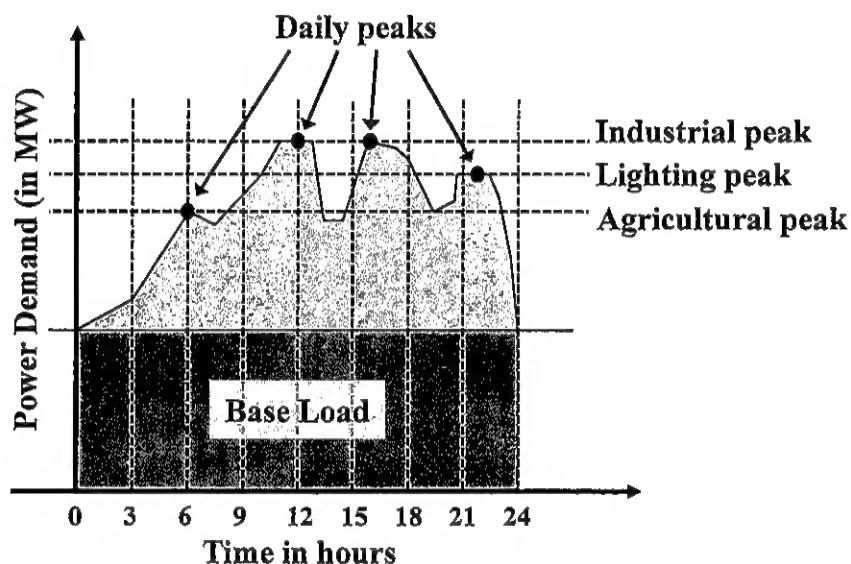


Figure Q4(a)

(b) Figure Q4(b) illustrates the one-line diagram of a power system. The ratings of the various components in the power system are listed as follows:

Generator, G: 100 MVA, 15 kV, $R = 40\%$, $X = 95\%$

Transformer, T1: 90 MVA, 15/360 kV, $R = 5\%$, $X = 9\%$

Transformer, T2: 75 MVA, 400/20 kV, $R = 5\%$, $X = 9\%$

Motor, M1: 85 MVA, 20 kV, $R = 18\%$, $X = 85\%$

Motor, M2: 60 MVA, 18 kV, $R = 12\%$, $X = 85\%$

The transmission line has an impedance of $(50 + j150) \Omega$. A common base apparent power of 100 MVA and base voltage of 15 kV at the generator side is selected for the system.

Continued...

(i) Find the base voltages and impedances in Regions 1, 2 and 3. [5 marks]

(ii) Sketch the impedance diagram of this power system, and label all the impedances in per-unit (p.u.) quantities. [7 marks]

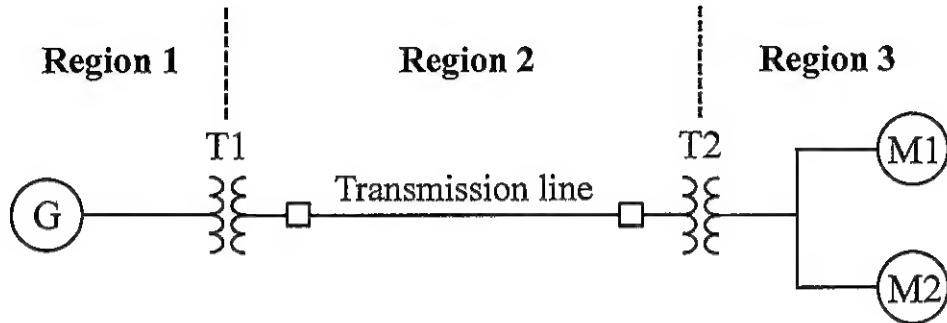


Figure Q4(b)

(c) Protective devices are introduced into a power system to protect people and equipment from malfunctions, regardless of whether the malfunction is caused by equipment failure, by weather or due to the carelessness of the operator. Explain the main function of the following protective devices:

- Circuit breaker
- Recloser

[4 marks]

(d) An Inverse Definite Minimum Time (IDMT) overcurrent relay is used to protect a distribution feeder. The time-delay characteristic of the relay is as shown in Figure Q4(d). The relay is connected to a 400:5 current transformer and a circuit breaker, and is set to operate when the load current on the feeder exceeds 800 A. For a chosen time-dial setting of 7, determine the operating time of the relay for a fault current of 3600 A. [5 marks]

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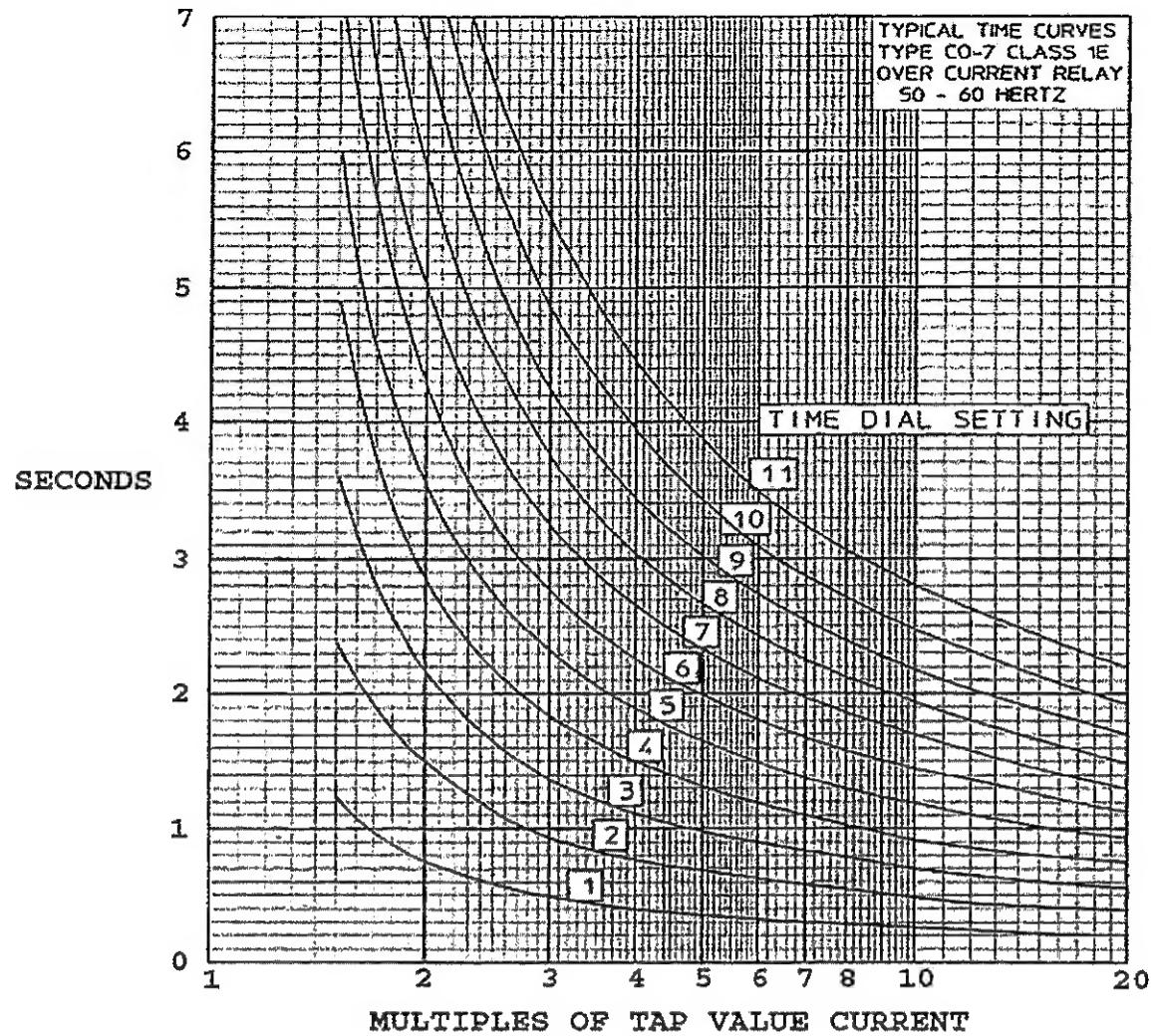


Figure Q4(c)

End of Question

APPENDIX

<u>Magnetic Circuits</u>	<u>Transformers</u>
$H = \frac{Ni}{l_c}$	Turn ratio: $a = \frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P}$
$B = \mu H = \mu_0 \mu_r H$	Equivalent circuit (referred to primary):
$\phi = BA$	$V'_S = aV_S, \quad I'_S = \frac{I_S}{a}$
$\mathfrak{R} = \frac{l_c}{\mu A}$	$R'_S = a^2 R_S, \quad X'_S = a^2 X_S, \quad Z'_L = a^2 Z_L$
$F = Ni = \phi \mathfrak{R} = Hl_c$	$R_{eqP} = R_P + a^2 R_S, \quad X_{eqP} = X_P + a^2 X_S$
$F = ilB \sin \theta$	Equivalent circuit (referred to secondary):
$e_{ind} = vLB \sin \theta_1 \cos \theta_2$	$V'_P = \frac{V_P}{a}, \quad I'_P = aI_P$
$P = \tau \omega$	$R'_P = \frac{R_P}{a^2}, \quad X'_P = \frac{X_P}{a^2}$
Three-Phase Circuits	$R_{eqS} = R_S + \frac{R_P}{a^2}, \quad X_{eqS} = X_S + \frac{X_P}{a^2}$
Y-Connection: $I_L = I_\phi, \quad V_L = \sqrt{3}V_\phi \angle 30^\circ$	Short-Circuit Test
Δ-Connection: $V_L = V_\phi, \quad I_L = \sqrt{3}I_\phi \angle -30^\circ$	$Z_{eq} = \frac{V_{SC}}{I_{SC}}, \quad R_{eq} = \frac{P_{SC}}{I_{SC}^2}$
Δ-Y Transformations:	$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$
$R_a = \frac{R_{ac}R_{ab}}{R_{ac} + R_{ab} + R_{bc}}$	Open-Circuit Test
$R_b = \frac{R_{ab}R_{bc}}{R_{ac} + R_{ab} + R_{bc}}$	$R_C = \frac{V_{OC}^2}{P_{OC}}, \quad S_{OC} = V_{OC}I_{OC}$
$R_c = \frac{R_{bc}R_{ac}}{R_{ac} + R_{ab} + R_{bc}}$	$Q_m = \sqrt{S_{OC}^2 - P_{OC}^2}$
Y-Δ Transformations:	$X_m = \frac{V_{OC}^2}{Q_m}$
$R_{ac} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_b}$	Voltage Regulation
$R_{ab} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_c}$	$VR = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$
$R_{bc} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_a}$	Efficiency $\eta = \frac{P_{out}}{P_{in}} \times 100\%$
$P_T = 3 V_\phi I_\phi \cos \theta = \sqrt{3} V_L I_L \cos \theta$	
$Q_T = 3 V_\phi I_\phi \sin \theta = \sqrt{3} V_L I_L \sin \theta$	
$S_T = 3 V_\phi I_\phi = \sqrt{3} V_L I_L $	

End of Paper

